HR-373 Investigation of Plastic Pipe for Highway Applications, Phases I & II

Key Words:

ABSTRACT: Phase I

In the past, culvert pipes were made only of corrugated metal or reinforced concrete. In recent years, several manufacturers have made pipe of lightweight plastic -for example, high density polyethylene (HDPE) - which is considered to be visco-elastic in its structural behavior. It appears that there are several highway applications in which HDPE pipe would be an economically favorable alternative. However, the newness of plastic pipe requires the evaluation of its performance, integrity, and durability. A review of the Iowa Department of Transportation **Standard Specifications for Highway and Bridge Construction** reveals limited information on the use of plastic pipe for state projects. The objective of this study was to review and evaluate the use of HDPE pipe in roadway applications. Structural performance, soil-structure interaction, and the sensitivity of the pipe to installation was investigated. Comprehensive computerized literature searches were undertaken to define the state-of-the-art in the design and use of HDPE pipe in highway applications.

A questionnaire was developed and sent to all Iowa county engineers to learn of their use of HDPE pipe. Responses indicated that the majority of county engineers were aware of the product but were not confident in its ability to perform as well as conventional materials. Counties currently using HDPE pipe in general only use it in driveway crossings. Originally, we intended to survey states as to their usage of HDPE pipe. However, a few weeks after initiation of the project, it was learned that the Tennessee DOT was in the process of making a similar survey of state DOT's. Results of the Tennessee survey of states have been obtained and included in this report.

In an effort to develop more confidence in the pipe's performance parameters, this research included laboratory tests to determine the ring and flexural stiffness of HDPE pipe provided by various manufacturers. Parallel plate tests verified all specimens were in compliance with ASTM specifications. Flexural testing revealed that pipe profile had a significant effect on the longitudinal stiffness and that strength could not be accurately predicted on the basis of diameter alone.

Realizing that the soil around a buried HDPE pipe contributes to the pipe stiffness, the research team completed a limited series of tests on buried 3 ft-diameter HDPE pipe. The tests simulated the effects of truck wheel loads above the pipe and were conducted with two feet of cover. These tests indicated that the type and quality of backfill significantly influences the performance of HDPE pipe. The tests revealed that the soil envelope does significantly affect the performance of HDPE pipe in situ, and after a certain point, no additional strength is realized by increasing the quality of the backfill.

Abstract: Phase II

It is generally accepted that high density polyethylene pipe (HDPE) performs well under live loads with shallow cover, provided the backfill is well compacted. Although industry standards require carefully compacted backfill, poor inspection and/or faulty construction may result in soils that provide inadequate restraint at the springlines of the pipes thereby causing failure. The objectives of this study were: 1) to experimentally define a lower limit of compaction under which the pipes perform satisfactorily, 2) to quantify the increase in soil support as compaction effort increases, 3) to evaluate pipe response for loads

applied near the ends of the buried pipes, 4) to determine minimum depths of cover for a variety of pipes and soil conditions by analytically expanding the experimental results through the use of the finite element program CANDE.

The test procedures used here are conservative especially for low-density fills loaded to high contact stresses. The failures observed in these tests were the combined effect of soil bearing capacity at the soil surface and localized wall bending of the pipes. Under a pavement system, the pipes' performance would be expected to be considerably better. With those caveats, the following conclusions are drawn from this study.

Glacial till compacted to 50% and 80% provides insufficient support; pipe failure occurs at surface contact stresses lower than those induced by highway trucks. On the other hand, sand backfill compacted to more than I 10 pcf (17.3 kN/m^3) is satisfactory. The failure mode for all pipes with all backfills is localized wall bending.

At moderate tire pressures, i.e. contact stresses, deflections are reduced significantly when backfill density is increased from about 50 pcf (7.9 kN/m^3) to 90 pcf (14.1 kN/m^3) . Above that unit weight, little improvement in the soil-pipe system is observed.

Although pipe stiffness may vary as much as 16%, analyses show that backfill density is more important than pipe stiffness in controlling both deflections at low pipe stresses and at the ultimate capacity of the soil-pipe system. The rate of increase in ultimate strength of the system increases nearly linearly with increasing backfill density.

When loads equivalent to moderate tire pressures are applied near the ends of the pipes, pipe deflections are slightly higher than when loaded at the center. Except for low density glacial till, the deflections near the ends are not excessive and the pipes perform satisfactorily. For contact stresses near the upper limit of truck tire pressures and when loaded near the end, pipes fail with localized wall bending.

For flowable fill backfill, the ultimate capacity of the pipes is nearly doubled and at the upper limit of highway truck tire pressures, deflections are negligible.

All pipe specimens tested at ambient laboratory room temperatures satisfied AASHTO minimum pipe stiffness requirements at 5% deflection. However, nearly all specimens tested at elevated pipe surface temperatures, approximately 1229F (50*C), failed to meet these requirements. Some HDPE pipe installations may not meet AASHTO minimum pipe stiffness requirements when installed in the summer months (i.e. if pipe surface temperatures are allowed to attain temperatures similar to those tested here). Heating of any portion of the pipe circumference reduced the load carrying capacity of specimens.

The minimum soil cover depths, determined from the CANDE analysis, are controlled by the 5% deflection criterion. The minimum soil cover height is 12 in. (305 mm). Pipes with the poor silt and clay backfills with less than 85% compaction require a minimum soil cover height of 24 in. (6 10 mm). For the sand at 80% compaction, the A36 HDPE pipe with the lowest moment of inertia requires a minimum of 24 in. (610 mm) soil cover. The C48 HDPE pipe with the largest moment of inertia and all other pipes require a 12 in. (305 mm) minimum soil cover.